A nine year survey of the vertebrate fauna of the Bruxner-Ulidarra conservation area in the New South Wales north coast bioregion

Michael J. Murphy[1] **and Sam P. Murphy**[2]

[1] NSW National Parks and Wildlife Service PO Box 105 Baradine NSW 2396

[2] 'Blackbird Grange' Rundle Street Coonabarabran NSW 2357

ABSTRACT

Bruxner Park Flora Reserve and the adjoining Ulidarra National Park, on the NSW north coast, comprise a dual-tenure conservation area of 1090 ha dominated by rainforest and old-growth moist eucalypt forest. A field survey of the area's vertebrate fauna over the period 1996-2005 detected 224 native species and nine introduced species. Incorporating records from secondary sources, the Bruxner-Ulidarra conservation area is known to support 230 native vertebrate species (39 mammals, 124 birds, 36 reptiles, 21 frogs and 10 fishes), including 20 species that are currently listed as threatened under NSW legislation. One hundred and ninety vertebrate species (79% of the total) were recorded during a systematic survey, with the remainder of records from opportunistic survey (18%) or secondary sources (3%). The effectiveness of the systematic survey effort in detecting the full inventory of species known from the study area ranged from 100% for freshwater fishes to only 61% for reptiles. Many reptile species were cryptic and/or at low density, and the resulting low detectability could easily have been mistaken for low reptile species diversity. This study demonstrates that a range of complementary survey methods over an extended period of time is needed to adequately sample the largest proportion of an area's total suite of vertebrate fauna. Suggestions are made concerning how to optimise results from vertebrate fauna inventory surveys.

Key words: rainforest, eucalypt forest, mammals, birds, reptiles, amphibians, freshwater fishes, survey completeness, threatened species.

Introduction

> *"What beasts there were in the wood even Threl (the hunter) did not know: many kinds fell to his subtlety, but who knew if these were all"* (Dunsany 1924).

The New South Wales (NSW) north coast bioregion (Thackway and Creswell 1995) contains a wide range of forest habitats and supports one of the richest assemblages of vertebrate fauna in NSW, including many species endemic to the region or with distributional strongholds there (Gilmour and Parnaby 1994). The region is also under continuing pressure from the resource demands of a steadily increasing human population, and much of the landscape has been modified through clearing for agriculture and urban development, forestry, stock grazing, changes to natural fire regimes and regulation of water flows. Within 17 decades of the start of European occupation, 37% of the region's original vegetation had been cleared and 21% of the region was devoted to intensive agricultural or pastoral production (State of the Environment Advisory Council 1996). Areas set aside as conservation reserves play an important part in the protection of the region's biodiversity. Effective management of these reserves requires knowledge of the species and communities present and their ecological requirements in order to maintain biodiversity values. The first aim of this study was to use a range of systematic fauna survey techniques to document as completely as possible the vertebrate fauna of Bruxner Park Flora Reserve (FR) and Ulidarra National Park (NP), including information on species' relative abundance, habitat preferences and conservation significance.

Site inventories of species based on field sampling have an inherent biased error in that some species present may be missed (Cameron and Pokryszko 2005). While many vertebrate species can be readily detected in the field with a relatively modest survey effort, provided appropriate methods of detection are used, species that are elusive and trap-shy, sparsely or patchily distributed or only irregular visitors to an area may only be reliably detected in longer term or greater intensity surveys (Barker *et al*. 1994; Debus 1995; Woinarski *et al*. 2000; Kutt *et al.* 2005). The second aim of this study was to consider how effective the systematic survey had been in detecting the full suite of species present. Methods of estimating the completeness of survey inventories include cumulative species curves and various statistical tools (e.g. Barker *et al*. 1994; Schilthuizen and Rutjes 2001; Clemann *et al.* 2005). The close proximity of the Bruxner-Ulidarra study area to the authors' residence at the time of this study enabled an alternate approach to examining the effectiveness of the systematic survey, with fauna records from extensive opportunistic or incidental surveying over a nine year period, together with records from secondary sources, being used to supplement the systematic survey species inventory.

Methods

Study Area

Bruxner Park FR and Ulidarra NP (Fig. 1) are located near Coffs Harbour in *Gumbaynggirr* Aboriginal Country in the NSW north coast bioregion. The climate is subtropical maritime with an average annual rainfall of about 2000 mm (Forestry Commission of NSW 1989). Bruxner Park (407 ha) is managed by Forests NSW and Ulidarra NP (683 ha) is managed by the NSW National Parks and Wildlife Service (NPWS). Together, the two reserves occupy a 1090 ha area of steep to undulating topography with an elevation range of 120-414m AHD and an underlying geology of metamorphosed shale. The Bruxner-Ulidarra study area is part of a larger forested area (about 9700 ha) associated with the sub-coastal escarpment backing this part of the coastal plain.

Four broad vegetation associations were identified in the study area. Closed forest (subtropical rainforest) occupies about 424 ha along the main gullies and lower slopes. Open forest (dry sclerophyll forest) dominated by Blackbutt *Eucalyptus pilularis* with a shrubby understorey occupies about 618 ha on mid to higher slopes and ridge tops. Tall open forest (wet sclerophyll forest) (about 38 ha) dominated by Flooded Gum *Eucalyptus grandis* with a secondary layer of smaller rainforest trees occurs on alluvial flats and lower slopes. Open forest (dry sclerophyll forest) with a variety of eucalypt species and a grassy understorey occurs in limited areas (about 10 ha) on north-facing upper

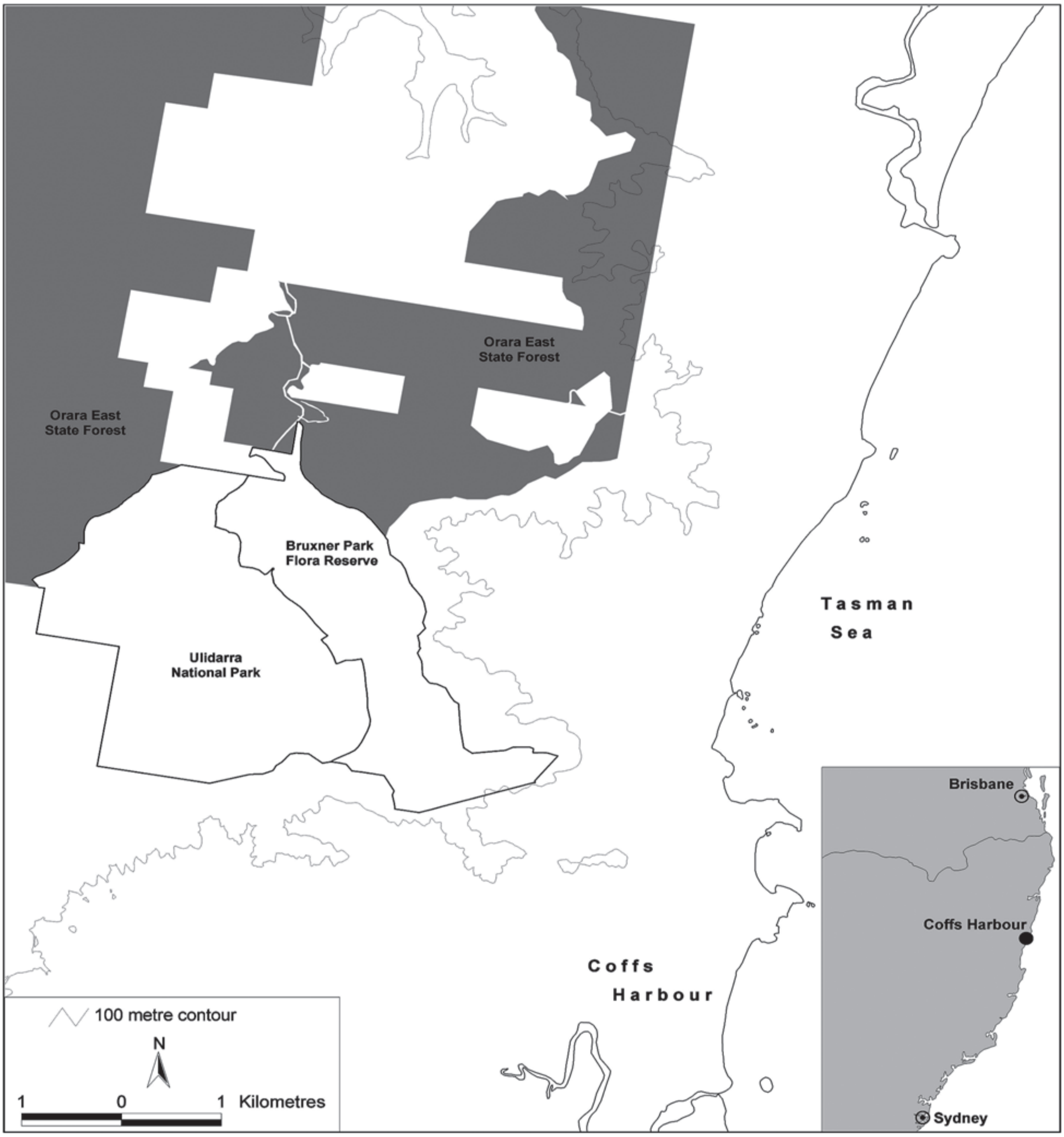

Figure 1. Location of Bruxner-Ulidarra study area near Coffs Harbour on the NSW north coast. The study area forms a localised easterly thrusting of the sub-coastal escarpment to within less than 2km of the coastline.

slopes and hilltops in the eastern part of the study area. Much of the three open forest habitats comprise old-growth forest. Bucca Bucca Creek (a minor upper tributary of the Orara River in the Clarence River system) originates in the study area as 1st to 3rd order streams comprising a series of shallow riffle zones linking deeper pools about 1-2 m deep. A section of 4th order stream with a large pool about 3 m deep located just outside the northern boundary of Bruxner Park was included as part of the study area.

Survey effort

A systematic field survey utilising a range of standard fauna survey techniques (Table 1) was done between 1996 and 2002 to sample the vertebrate species present in the study area. This survey initially targeted reptiles and amphibians (from 1996), but was expanded to include birds (from 1999) and mammals and fishes (from 2000). The survey period included climatic conditions ranging from high rainfall to drought.

Table 1. Systematic fauna survey methods employed in this study.

Survey method & target group	Description	Survey effort
Timed nocturnal searches (fishes)	30 minute search at night of 100m transect along creek using spotlight and dip-net.	10 surveys along each of 4 transects (3 rainforest, 1 tall open forest).
Timed nocturnal searches (frogs)	30 person-minutes search at night along a 100m transect: listening for calls and searching by spotlight for active animals. Surveys October-March during or following rain, and only when at least one frog species audible at site.	12 surveys along each of 5 transects: 4 on creeks (3 in rainforest and 1 in tall open forest) and 1 in roadside gutter in grassy open forest.
Timed diurnal searches (reptiles)	1 person-hr search over a 2ha site on warm, dry days Oct-March: using direct observation and investigation of potential shelter sites.	60 sites stratified by vegetation type.
Artificial shelter sites (elapid snakes)	Sheets of corrugated roofing iron placed on ground and inspected early morning at intervals Nov 1997-May 1998.	4 sites (5-6 sheets per site) stratified by vegetation type. Total of 440 sheet-inspections.
Dry pitfall traps (small ground active & fossorial reptiles & frogs)	Trap-lines of five 270mm deep pitfalls linked by a 10m drift fence. Six trapping sessions (each session 5 days) Nov 1997-April 1998. Traps closed between sessions.	4 sites stratified by vegetation type. Total effort 600 trap-days.
Aquatic drum traps (turtles)	35 x 40 x 65cm wire drum trap baited with fresh meat/ox liver and set partially submerged in 3m deep pool in creek.	3 trap-days.
Timed diurnal census (diurnal birds)	1 hr census over 2ha site, listing all species seen or heard. Done on days with minimal wind Oct 1999-Sept 2000.	200 sites stratified by vegetation type and season.
Call playback (nocturnal birds)	Taped calls of Powerful Owl, Barking Owl, Sooty Owl, Masked Owl, Barn Owl and Marbled Frogmouth broadcast through a loudspeaker, followed by periods of listening and spotlighting. Done on dry nights with minimal wind.	26 sites stratified by vegetation type.
Timed nocturnal search (nocturnal birds & mammals)	30 minute search over 2ha site. Comprised spotlighting and listening for calls. Done on dry nights with minimal wind.	60 sites stratified by vegetation type.
Ground-based Elliott traps (small terrestrial mammals)	Size A traps baited with peanut butter/rolled oats set at ground level and checked daily for 4 days.	30 sites stratified by vegetation type. Total of 600 trap-nights.
Tree-based Elliott traps (small arboreal mammals)	Size A and E traps baited with peanut butter/rolled oats/honey set on brackets on tree trunks 2m above ground and checked daily for 4 days.	12 sites stratified by vegetation type. Total of 240 trap-nights.
Cage traps (quolls)	30 x 30 x 60cm trap baited with fresh meat set at ground level and checked daily for 4 days.	35 sites stratified by vegetation type. Total of 140 trap-nights.
Dawn census (Platypus)	Early morning observation for 1 hr/day at 3m deep pool in creek.	5 hours
Predator scat searches (non-volant mammals)	Collection of mammalian predator scats from across study area. Analysis by scat specialist Barbara Triggs.	104 predator scats
Harp-trapping (microchiropteran bats)	Harp-trap set across likely flyway for 2 consecutive nights. Done Oct-March except for 3 sites sampled in August.	19 sites stratified by vegetation type. Total of 38 trap-nights.
Ultrasonic recording (microchiropteran bats)	Microchiropteran bat calls recorded over 30 min using hand-held ultrasonic detector (Anabat: Titley Electronics). Done between dusk and 2 hours post-dusk on dry, calm nights Nov-Jan. Analysis of recorded calls by bat specialist Glenn Hoye.	11 sites stratified by vegetation type.

In addition to the systematic survey, opportunistic or random surveying of all vertebrate groups throughout the study area was done during 655 field visits between March 1996 and February 2005, with methods including direct diurnal observation, searching of potential shelter or roost sites, call recognition, nocturnal observation either by spotlight on foot or using car headlights while driving slowly along roads, snorkelling, dip-netting, tadpole identification, identification of indirect signs and checking roads for animals killed by motor vehicles. Opportunistic observations were generally only documented when a previously unrecorded species was found, when species had been infrequently recorded during systematic surveys or when a species was found in a previously unrecorded habitat or by a different method of detection. A range of secondary sources were also consulted to compile records of additional vertebrate species in the study area. This included published literature, unpublished reports held by Forests NSW, the NPWS Atlas of NSW Wildlife and communication with other researchers and naturalists.

Taxonomy

Taxonomic nomenclature in this paper follows McDowell (1996) for fishes, Barker *et al.* (1995), Donnellan *et al.* (1999) and Donnellan and Mahony (2004) for frogs, Swan *et al.* (2004) for reptiles, Christidis and Boles (1994) for birds and Menkhorst and Knight (2001) for mammals. Voucher specimens of many of the fish, frog, small reptile and small mammal species recorded were lodged in the Australian Museum (Sydney) to substantiate records and to provide reference material in the event of future taxonomic revisions. Common names for birds are used in the results and discussion sections of this paper, while only scientific names are generally used for other vertebrate groups.

Results

Species recorded

Combining the results from the 1996-2005 field survey with information from secondary sources identified 240 vertebrate species in the Bruxner-Ulidarra study area, comprising 47 mammals, 126 birds, 36 reptiles, 21 frogs and 10 fishes. Eight mammals and two birds are introduced taxa. A complete list of the vertebrate fauna known from the study area is provided in Appendix 1, together with information on methods of detection or source of record, habitat usage, number of records documented during the field survey and voucher specimens collected.

Twenty species recorded from the study area are of state-level conservation concern, currently listed under the NSW *Threatened Species Conservation Act* 1995 (TSC Act). *Mixophyes iteratus* is currently listed as endangered (higher risk) while 19 species are listed as vulnerable (lower risk). Another three threatened (vulnerable) species recorded in close proximity and with suitable habitat available within the study area are considered to potentially occur in the Bruxner-Ulidarra study area. Information concerning records of threatened species is summarised in Appendix 2.

The number of species from each fauna group recorded in each broad habitat type is shown in Table 2. Shrubby open forest had the greatest number of species recorded, including the most mammal, bird and reptile species, while rainforest had the greatest number of frog species. Grassy open forest supported relatively few species, although this included 11 species only recorded in this habitat (Appendix 1). Seven bird species were only recorded flying high over the study area (Appendix 1).

Rhadinocentrus ornatus was the most frequently detected fish species (recorded in 100% of systematic fish survey transects), followed by *Gobiomorphus australis* (97%) and *Anguilla reinhardtii* (80%). Rarely recorded species included *Retropinna semoni* and *Melanotaenia duboulayi*. The systematic survey indicated that most species decreased in frequency of detection with distance upstream. Overall fish species diversity decreased with distance upstream (9 – 8 – 5 species at 3 sequential sites on one stream).

Common frogs in Bruxner-Ulidarra included *Litoria* sp. C (as described by Donnellan *et al.* 1999) (present at 75% of systematic frog transects), *Adelotus brevis* (52%) and *Litoria wilcoxii* (42%). Rarely recorded species included *Litoria caerulea* and *Litoria revelata*. One frog community was associated with streams in rainforest and tall open forest and included *Litoria* sp. C, *Litoria phyllochroa* and *Mixophyes iteratus*, while a different suite of species, including *Litoria latopalmata*, *Litoria peronii* and *Uperoleia fusca*, was associated with temporary puddles in open forest. Up to six species were recorded together at one time at streamside systematic sites (mean 2.8 species) and up to nine species at the roadside gutter systematic site in open forest (mean 4.7).

Many reptile species in the study area were cryptic and/or uncommon. A quarter of all reptile species found were represented by three or less records each despite considerable systematic and opportunistic survey effort for reptiles. One species, *Lampropholis delicata*, was abundant (recorded in 75% of timed reptile searches and comprising

Table 2. Summary of the number of species from each vertebrate group recorded in each broad habitat type.

Habitat type	Mammals	Birds	Reptiles	Frogs	Fishes	Total (all taxa)
Rainforest	28	65	23	15	-	131
Tall Open Forest	21	78	18	12	-	129
Shrubby Open Forest	32	91	31	14	-	168
Grassy Open Forest	21	68	16	12	-	117
Aquatic	2	7	3	5	10	27
Aerial	1	11	-	-	-	12
Total (all habitats)	47	126	36	21	10	

over half of all reptile records documented). Other relatively common species included *Saproscincus rosei* (27% of timed searches), *Varanus varius* (18%) and *Egernia major* (15%). Rarely recorded species included *Pygopus lepidopodus* and *Eulamprus tenuis* (the latter only recorded on the final day of the survey).

The most frequently recorded diurnal bird was the Lewin's Honeyeater *Meliphaga lewinii* (recorded at 90% of systematic diurnal bird sites), followed by the Grey Fantail *Rhipidura fuliginosa* (76%) and Grey Shrike-thrush *Colluricincla harmonica* (65%). Uncommon species included the Red-browed Treecreeper *Climacteris erythrops* and White-cheeked Honeyeater *Philidonyris nigra*. The systematic survey indicated seasonal variation in the diurnal bird fauna, with 72 species recorded in spring, 70 in summer, 65 in autumn and 59 in winter. Species with apparent seasonal patterns included spring/summer visitors (Rose-crowned Fruit-dove *Ptilinopus regina*, Common Koel *Eudynamys scolopacea* and Black-faced Monarch *Monarcha melanopsis*) and those with notable peaks in recording rates in autumn (Topknot Pigeon *Lopholaimus antarcticus* and Rufous Fantail *Rhipidura rufifrons*) and winter (Yellow-faced Honeyeater *Lichenostomus chrysops*). The Southern Boobook *Ninox novaeseelandiae* was the most frequently recorded nocturnal bird (recorded in 48% of systematic spotlight surveys).

Common non-volant mammals included *Antechinus stuartii* (13 captures/100 ground-based Elliott trap-nights), *Trichosurus vulpecula* (recorded in 32% of systematic spotlight surveys) and *Wallabia bicolor* (detected in 42% of predator scats). Rarely recorded species included *Sminthopsis murina* and *Cercartetus nanus*. Ground and tree-based Elliott trapping revealed different patterns of habitat utilisation by the two common native rodents, with *Melomys cervinipes* predominantly arboreal (2 captures/100 trap-nights on ground and 11 captures/100 trap-nights in trees) while *Rattus fuscipes* was exclusively terrestrial (12 captures/100 trap-nights on ground and nil in trees). The study also revealed a diverse bat fauna (18 species), including fruit bats and both tree hollow- and cave-roosting microchiropteran species. Searches of rock crevices and culverts did not locate any microchiropteran roosts, but one *Nyctophilus gouldi* was found roosting inside the hollow trunk of a large Flooded Gum.

Survey effectiveness

A total of 190 vertebrate fauna species were detected during the systematic survey (Appendix 1). Table 3 shows the number of species recorded by each systematic survey method as well as the number of species unique to that method (within the systematic survey). Timed searches were the most productive survey method for frogs and reptiles. Pitfall trapping and artificial shelter sites detected relatively few species but both added to the species total for reptiles. Timed spotlight searches and analysis of predator scats were the most productive survey methods for non-volant mammals, with ground-based Elliott trapping adding one additional species (*Rattus lutreolus*). Harp trapping and ultrasonic recording were complementary methods for the detection of microchiropteran bats, with only three species recorded by both methods. The use of aquatic drum traps, tree-based Elliott traps, cage traps, call playback and dawn census were all redundant in this study with respect to identifying additional species.

The extensive opportunistic survey effort over nine years identified an additional 43 species and reference to secondary sources added another seven species (see Appendix 1). This included six of the 20 threatened vertebrate species known from the study area.

The effectiveness of the systematic survey effort in detecting the full range of species present in the study area was examined by comparing the systematic results against the more complete species inventory achieved by pooling all systematic, opportunistic and secondary records (the best available approximation of the full

Table 3. Summary of results from systematic survey: number of target species recorded by each method and number of species unique to that method (within systematic survey).

Survey method & target group	No. species recorded	No. species recorded only by this method
Timed nocturnal searches (fishes)	10	10
Timed nocturnal searches (frogs)	17	15
Timed diurnal searches (reptiles)	17	10
Artificial shelter sites (reptiles)	5	1
Pitfall traps (frogs & reptiles)	2 frogs & 9 reptiles	0 frogs & 4 reptiles
Aquatic drum traps (reptiles)	1	0
Timed diurnal census (birds)	94	94
Nocturnal call playback (birds)	2	0
Timed nocturnal searches (birds & mammals)	6 birds & 13 mammals	4 birds & 5 mammals
Ground-based Elliott traps (mammals)	4	1
Tree-based Elliott traps (mammals)	2	0
Cage traps (mammals)	3	0
Dawn census (mammals)	1	0
Predator scat analysis (mammals)	20	11
Harp-trapping (mammals)	7	4
Ultrasonic recording (mammals)	10	7

species inventory). The results varied between fauna groups: 100% for fishes, 87% for mammals, 81% for frogs, 79% for birds and only 61% for reptiles. The results for a selection of the individual systematic survey methods are shown in Table 4. Scat analysis and timed searches for fishes, frogs and diurnal birds all succeeded in detecting half of the target species known to be present within less than a quarter of the survey effort, and over two thirds of target species by the end of the survey effort. Ultrasonic bat detection took relatively longer to reach half of the species present and achieved just under two thirds of target species in total. In contrast, even at the end of the timed reptile search survey effort, less than half of the total reptile species known from the study area had been recorded. The shape of the cumulative species curves from these systematic survey methods (Fig. 2 a-f) give an indication of the likely additional survey effort needed to record further species.

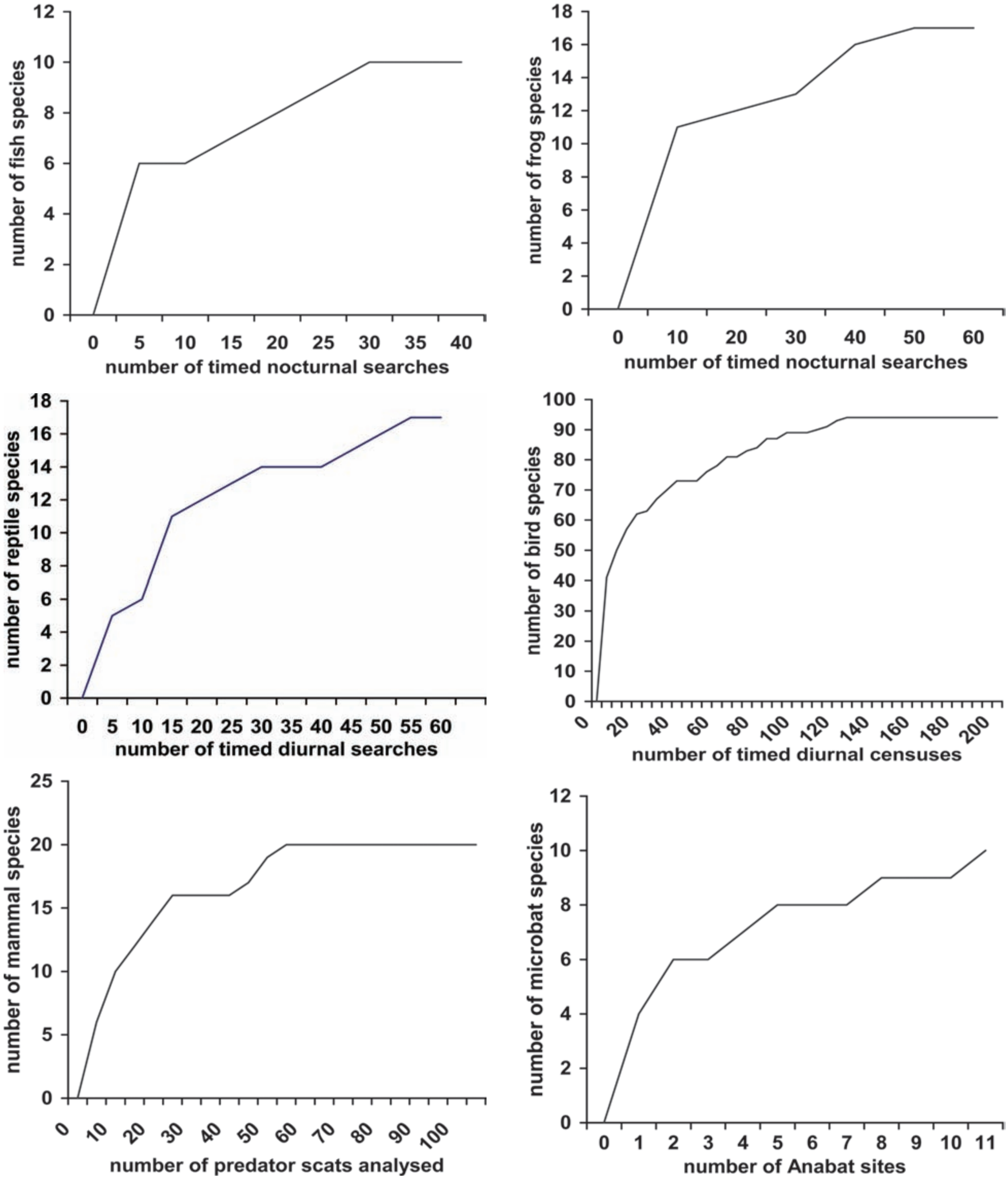

Figure 2 (a-f). Cumulative species curves showing return for effort for selected systematic survey methods: (a) = timed nocturnal searches for fishes, (b) = timed nocturnal searches for frogs, (c) = timed diurnal searches for reptiles, (d) = timed diurnal census for birds (order of sites randomised to counter seasonal effects), (e) = predator scat analysis for non-volant mammals and (f) = ultrasonic recording for microchiropteran bats.

Table 4. Effectiveness of selected systematic survey methods in detecting target species known to be present. Systematic survey results are compared against the more complete inventory derived by pooling systematic, opportunistic and secondary source records.

Survey method and target group	Survey effort to record 50% of target species	Proportion of target species recorded by end of survey effort
Timed nocturnal searches (fishes)	1 hr	100% after 20 hrs
Timed nocturnal searches (frogs)	3 hrs	81% after 30 hrs
Timed diurnal searches (reptiles)	-	47% after 60 hrs
Timed diurnal census (diurnal birds)	18 hrs *	78% after 200 hrs
Predator scat analysis (non-volant mammals)	23 scats	69% after 104 scats
Ultrasonic recording (microchiropteran bats)	2.5 hrs	63% after 5.5 hrs

*Sites randomised to counter seasonal effects

Discussion

Biogeographic context

This study documented a remarkably rich vertebrate fauna assemblage, considering the small size of the study area and limited variety of habitats present. The 230 native species known from the study area represent approximately 14, 27, 17, 26 and 30% respectively of the NSW freshwater fish, amphibian, reptile, bird and mammal native faunas (Faragher and Harris 1994; Lunney *et al.* 2004). A major factor contributing to the area's high species diversity is its geographical position in a transitional zone between the southern Bassian, northern Torresian and eastern highland Tumbunan faunal divisions (Kikkawa and Pearce 1969; Schodde 1979). Such transitional areas typically have higher inherent species diversities, resulting from overlapping fauna assemblages, and are therefore considered of particular significance for conservation (Milledge 1991; Spector 2002). The NSW north coast bioregion is also a significant centre of endemism, related in part to the long-term influence of Tertiary volcanic activity on landform, habitats and evolutionary processes (Webb *et al.* 1984; Musyl and Keenan 1996). Many of the species recorded in this study are endemic to the NSW north coast or have a distributional stronghold there (Gilmour and Parnaby 1994; Morris *et al.* 2001).

Species of conservation significance

A relatively high number of species of conservation significance are now known from the Bruxner-Ulidarra study area. Twenty vertebrate species listed under the NSW TSC Act have been recorded in the study area, and another three species with suitable habitat available have been recorded within 1-2 km (Appendix 2).

The Giant Barred Frog *Mixophyes iteratus* was the species of highest conservation significance recorded, listed as endangered at both the state (NSW TSC Act) and national (Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999) levels. The distribution of this large frog previously extended to the NSW south coast but it has declined markedly in range and abundance with the causal processes remaining uncertain (Mahony 1993; Ehmann 1997). An apparent local decline in abundance was noted over the course of the study; possibly related to the drought conditions prevalent during the latter part of the study or part of the wider continuing decline of the species. A strong breeding response was noted when heavy rainfall ended an extended dry period, with the normally nocturnal species continuing to call throughout the day.

The Stephen's Banded Snake *Hoplocephalus stephensii* spends a considerable proportion of the time sequestered within arboreal retreat sites (Fitzgerald *et al.* 2002a), and the number of sightings in this study probably indicates a relatively large population. Presence of *H. stephensii* is considered an indication of high habitat quality, as the species is reliant on large forest blocks with abundant hollow-bearing trees and diverse vertebrate prey species (Fitzgerald *et al.* 2002b, 2004; Keogh *et al.* 2003). Data from the Bruxner-Ulidarra population contributed to research into the ecology and phylogeography of the species (Keogh *et al.* 2003; Fitzgerald *et al.* 2004).

The Black Bittern *Ixobrychus flavicollis*, a cryptic species of sheltered waterways, was recorded only once, with a single bird observed at a remnant creek line pool during drought conditions. This sighting, together with observations of the White-necked Heron *Ardea pacifica* and Nankeen Night Heron *Nycticorax caledonicus* under similar conditions, suggests that such sites may be valuable as local drought refugia.

Rainforest areas supported a suite of frugivorous bird species, including the threatened Wompoo Fruit-dove *Ptilinopus magnificus*, Rose-crowned Fruit-dove and Barred Cuckoo-shrike *Coracina lineata* (recorded in the study area) and the Superb Fruit-dove *P. superbus* (recorded within 1 km of the study area) (Appendix 2). Fruiting Strangler Figs *Ficus watkinsiana* were noted as favoured feeding sites for the Wompoo Fruit-dove. All three fruit-dove species are considered at risk of further decline (Moran *et al.* 2004). Conservation of these species requires the retention of suitable rainforest habitat along both latitudinal and altitudinal gradients (Date *et al.* 1991).

A suite of threatened species recorded within the study area (Glossy Black-cockatoo *Calyptorhynchus lathami*, Barking Owl *Ninox connivens*, Powerful Owl *N. strenua*, Sooty Owl *Tyto tenebricosa* and Yellow-bellied Glider *Petaurus australis*) or in close proximity (Masked Owl *T. novaehollandiae* and Spotted-tailed Quoll *Dasyurus maculatus*) rely on large tree hollows for breeding, denning and/or prey availability (Scotts 1991; Kavanagh *et al.* 1995; Gibbons and Lindenmayer 2002). Areas of old growth forest provide valuable habitat for these and a range of other species.

This study revealed a particularly rich microchiropteran bat fauna, constituting 41% of the native mammal species recorded and including five threatened species (*Kerivoula papuensis*, *Miniopterus australis*, *M. schreibersii*, *Myotis macropus* and *Scoteanax rueppellii*). Fourteen species were detected with only a modest survey effort, with another two added from secondary sources (Appendix 1). As expected (based on the paucity of rock outcrops), the microchiropteran fauna comprised mainly tree hollow-roosting species, with only four cave-roosting species as well as one species (*K. papuensis*) which utilises disused nests of gerygones and scrubwrens (Churchill 1998).

Migrants and irregular visitors

Seasonal migrants made up a significant component of the avifauna, with a 22% increase in diurnal bird species diversity between winter and spring. Prominent spring/summer visitors included the Sacred Kingfisher *Todiramphus sanctus*, Black-faced Monarch and Spangled Drongo *Dicrurus bracteatus*. Autumn/winter migrants were less obvious but included the Rose Robin *Petroica rosea* and Silvereye *Zosterops lateralis*. The coastal plain adjacent to the study area is a natural bottleneck less than 2km wide (Fig. 1), further reduced as a result of clearing for agriculture and urban development, and the forested slopes of the eastern part of the study area are an important passageway for migratory forest species moving north or south through this part of the coast.

A range of additional mobile species used the study area on an irregular basis. Many species of frugivorous and nectivorous birds and fruit bats undertake movements at local and regional scales in response to the irregular availability of food resources (Date *et al*. 1991; Milledge 1991; Franklin and Noske 1998). During the present study, an influx of Topknot Pigeons coincided with fruiting of Bangalow Palm *Archontophoenix cunninghamiana* and occasional visits by the Little Red Flying Fox *Pteropus scapulatus* coincided with flowering of Blackbutt. Flocks of lorikeets moved between the study area and adjacent coastal plain forests, probably in response to local flowering events, while the Little Wattlebird *Anthochaera chrysoptera* was a rare visitor from coastal heaths.

Habitat values

The small streams in the study area support a surprisingly diverse aquatic fauna. The ten fish species represent 37% of the known fish fauna of the entire Orara River system (Anderson and Howland 1998; Cashner *et al*. 1999). Deeper pools in the lower part of the study area supported species (*Emydura macquarii*, *Ornithorhynchus anatinus* and several fishes) not found elsewhere in the study area and also formed water sources during drought. The riparian vegetation is an important factor in creating and maintaining instream habitat complexity (Scotts 1991; Koehn 1993).

Rainforest and moist eucalypt forest are the dominant terrestrial habitats in the study area and support populations of many species of conservation significance. The Bruxner-Ulidarra area is significant as one of the few lowland rainforest sites remaining on the NSW north coast (Date *et al.* 1991). Old growth forest elements in the study area, including hollow-bearing trees (both living trees and stags) and coarse woody debris on the forest floor and in streams, provide valuable habitat for a wide range of species.

The small areas of grassy open forest (only 1% of the study area) make a noteworthy contribution to the area's overall conservation value. Seven threatened species were recorded in this habitat and 11 vertebrate species were recorded only there. Additional biodiversity values of these areas include the occurrence of an undescribed species of narrow-range camaenid land snail (Murphy 2007) and their use as hilltopping sites (i.e. congregation for mating) by a suite of butterfly species (authors pers. obs.).

Survey effectiveness

Several studies have examined the relative effectiveness of various fauna survey methods (e.g. Milton 1980; Schulz and de Oliveira 1995; Catling *et al.* 1997; Parris *et al*. 1999; Garden *et al*. 2007). The common finding is that a range of complementary methods is required to comprehensively survey an area's fauna. In the present study, 11 of the 16 systematic survey methods contributed to the overall species inventory. Two of these added only one species each, but the remaining nine (timed nocturnal searches for fishes, frogs and mammals/birds, timed diurnal searches for reptiles and birds, pit-fall trapping, predator scat analysis, harp trapping and ultrasonic recording) accounted for 78% of the species recorded and would all be part of the minimum suite of methods recommended for effective survey of the area's total vertebrate fauna.

Five systematic survey methods used were redundant with respect to detecting additional species. This is not to imply that these methods cannot be of value. The use of aquatic drum traps for turtles and dawn census for platypus were redundant because the target species were fortuitously identified by alternate methods, but both remain reliable means of detecting the target species. Call playback for nocturnal birds, tree-based Elliott trapping and cage trapping all failed to detect additional species, but the survey effort expended for all three was limited and, with further survey effort, these methods may have added species such as the Masked Owl, Feathertail Glider *Acrobates pygmaeus* and Spotted-tailed Quoll. Different survey methods can also be useful in providing ecological or behavioural information. Tree-based Elliott trapping, for example, revealed that *Melomys cervinipes* was more common in the study area than ground-based trapping had suggested. This rodent makes extensive use of the arboreal environment, so that traps placed in trees are more likely to be encountered by the species during normal activities (Wood 1971; Tasker and Dickman 2002).

Reptiles were the fauna group most under-sampled in the systematic survey. Nine years of survey eventually revealed a reptile fauna with high species diversity. Reptiles were not an obvious component of the overall fauna, however, and many species had only low rates of detection, due to low density and/or cryptic habits. This low detectability could very easily have been mistaken for low species diversity if less survey effort had been expended. Other long-term reptile studies have similarly noted the time or effort needed to fully document an area's reptile fauna (Lunney and Barker 1986; Schulz 1993). Woinarski *et al.* (2000) noted that snakes in particular are typically under-sampled by standard field survey methods. Milton (1980) identified road transects as the most reliable method for detecting snakes. Opportunistic surveying while driving slowly along roads on warm, humid evenings (when snakes often bask on the warm road surface) was the most reliable method for detecting snakes in the present study, with all 13 species recorded in this manner over the course of the study. We recommend inclusion of nocturnal road transects for reptiles (if feasible) in the systematic survey design for future surveys of this type. It is worth noting, however, that success in this method required a considerable search effort. For example, in 100 km of car-based nocturnal searches over five nights in January-March 2001 (a very small fraction of the entire effort), only six individual snakes (3 species) were observed. It would appear that considerable survey effort can be needed to effectively sample the sometimes cryptic reptile fauna of rainforests and moist eucalypt forests.

Catling *et al.* (1997) noted that opportunistic recording, no matter how randomly done, is a valuable component of fauna surveys. Opportunistic survey accounted for 18% of the species recorded in the present study. The majority of the species added opportunistically were sparse or cryptic residents, had limited habitat available in the study area or were irregular visitors, but did include a number of species of conservation significance. Thirty species detected during the combined systematic and opportunistic field survey (13% of the total) were represented by only single records, suggesting that additional species may yet have been detected with further survey; a point borne out by the addition of seven species from secondary sources. This raises the question: how much survey effort is needed to identify an area's vertebrate fauna and can an area's species inventory ever be considered complete? Kemp and Kutt (2004) suggested that it is always better to err on the side of greater survey effort. In the present study, new species continued to be detected up to the final day. Time and budgets available for fauna field surveys are never unlimited, however, and eventually any survey will reach the point on the cumulative species curve where the possible detection of more species is not worth the additional effort required. The authors are confident that, through the combined efforts of systematic survey, opportunistic observations and reference to secondary sources, we have documented the majority of vertebrate species occurring in the Bruxner-Ulidarra study area and that, whilst at least some species would probably be added by further survey effort, most of these are likely to be only irregular visitors or very scarce residents.

Conclusion

Bruxner Park FR and Ulidarra NP support a very high diversity of native vertebrate fauna of conservation significance at a regional, state and national level. The reserves are too small to support the full range of vertebrate fauna present in isolation, and continued conservation of many species within the reserves will depend on sympathetic management of surrounding production forests and freehold forested lands. It is also suggested that, notwithstanding the differences in tenure, the two reserves would most effectively be managed in coordination. This study provides one of the most complete site-specific examples illustrating the significant diversity of the forest vertebrate fauna of the NSW north coast bioregion, and provides a useful reference point for long-term monitoring of any future changes in that fauna.

Based on our experience at Bruxner-Ulidarra, we identify the following points to optimise success in vertebrate fauna inventory surveys. None of these points are new but they are worth reiterating.

1. Use multiple complementary survey methods;
2. Include opportunistic (non-constrained) surveying as a significant dedicated component of the survey effort, particularly for reptiles;
3. Spread survey effort over maximum time period possible;
4. Stratify survey sites across all vegetation communities or broad habitats present;
5. Monitor return for effort from each systematic survey method employed;
6. Include targeted survey for species of conservation significance as well as general inventory surveying;
7. Research secondary sources of information concerning species records; and
8. Consider what additional undetected species may occur, based on assessment of species ranges, habitats available and local records.

Acknowledgements

We wish to thank Jess, Nicola and Sue Murphy for assistance and support over the duration of this study. Assistance was also provided at various stages by Dave Scotts, Mark Graham, Anna Lloyd, Glenn Hoye, Shane Ruming, John Turbill, Peter Richards, Ann Walton, Ross Sadlier, Michael Mahony, Paul Meek, John Hunter, David Page, David Rohweder, Darren Moffatt, Rod Kavanagh, Sonya Ardill, Cathy Eggert, Andrew Lo, Peter Higgins, Andrew Moriarty and Steve McEwan. This project was undertaken under NSW NPWS Scientific Investigation Licence A1362 and Animal Research Authorities 52 and 04120003, NSW Fisheries Scientific Research Permit F94/876 and Forests NSW Special Purposes Permits 05204 and 05538. Comments on an earlier draft manuscript by Brad Law and two anonymous referees greatly improved the final paper.

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APPENDIX I

Appendix 1. Vertebrate fauna of Bruxner Park Flora Reserve and Ulidarra National Park.

S = species recorded in systematic survey.

M = method of detection. **A** = active searching, **B** = dropboard (artificial shelter), **C** = cage trap, **CP** = call playback, **D** = direct diurnal observation, **E** = Elliott trap, **Ha** = harp trap, **He** = heard call, **I** = indirect signs, **N** = dip-netting, **PF** = pitfall trap, **Pr** = in mammalian predator scat, **R** = roadkill, **Sn** = recorded as prey of snake, **Sp** = spotlighting, **Ta** = tadpoles identified, **Tu** = turtle trap, **U** = ultrasonic recording.

H = habitat type. **A** = aquatic, **G** = grassy open forest, **H** = at height over study area, **R** = rainforest, **S** = shrubby open forest, **T** = tall open forest.

R = total number of records from 1996-2005 field survey including all systematic methods plus opportunistic observations noted. **B** = recorded in January 1982 by Bevan (1983), **L** = recorded in 2003 by Lloyd (2004), **R** = recorded in 1971 by Roberts (1971), **T** = reported in 1991 by T. Tweedie (Rod Kavanagh NSW Department of Primary Industries pers. comm.).

(TS) = species currently listed as threatened under NSW *Threatened Species Conservation Act* 1995. * = introduced species. **(v)** = voucher specimen(s) lodged in Australian Museum (Sydney).

Family	Species	Common name	S	M	H	R
Fishes						
Anguillidae	*Anguilla reinhardtii*	Long-finned Eel	×	D, N, Sp, Tu	A	82
Retropinnidae	*Retropinna semoni*	Australian Smelt (v)	×	N, Sp	A	1
Plotosidae	*Tandanus tandanus*	Freshwater Catfish (v)	×	N, Sp	A	7
Melanotaeniidae	*Melanotaenia duboulayi*	Duboulay's Rainbowfish (v)	×	N, Sp	A	2
Melanotaeniidae	*Rhadinocentrus ornatus*	Ornate Rainbowfish (v)	×	D, N, Sp	A	382
Gobiidae	*Gobiomorphus australis*	Striped Gudgeon (v)	×	N, Sp	A	50
Gobiidae	*Gobiomorphus coxii*	Cox's Gudgeon (v)	×	N, Sp	A	26
Gobiidae	*Hypseleotris compressa*	Empirefish (v)	×	N, Sp	A	11
Gobiidae	*Hypseleotris galii*	Firetailed Gudgeon (v)	×	N, Sp	A	23
Gobiidae	*Philypnodon* sp. 1	Dwarf Flathead Gudgeon (v)	×	N, Sp	A	3
Amphibians						
Hylidae	*Litoria* sp. C *'barringtonensis'*	Speckled Tree Frog (v)	×	D, He, Sp	ART	551
Hylidae	*Litoria caerulea*	Green Tree Frog		Sp	R	1
Hylidae	*Litoria chloris*	Red-eyed Tree Frog (v)	×	He, R, Sp	GRST	110
Hylidae	*Litoria dentata*	Bleating Tree Frog (v)	×	He, Sp	GRST	24
Hylidae	*Litoria fallax*	Eastern Dwarf Tree Frog (v)	×	He, Sp	AGS	16
Hylidae	*Litoria gracilenta*	Dainty Green Tree Frog (v)	×	He, Sp	ST	7
Hylidae	*Litoria latopalmata*	Broad-palmed Frog (v)	×	He, Sp	GR	23
Hylidae	*Litoria peronii*	Peron's Tree Frog (v)	×	He, R, Sp	RST	12
Hylidae	*Litoria phyllochroa*	Leaf Green Tree Frog (v)	×	He, Sp	ART	119
Hylidae	*Litoria revelata*	Whirring Tree Frog (v)		He, R, Sp	GS	2
Hylidae	*Litoria tyleri*	Tyler's Tree Frog		He, Sp	RS	3
Hylidae	*Litoria wilcoxii*	Wilcox's Frog (v)	×	He, R, Sp	GRST	133
Myobatrachidae	*Adelotus brevis*	Tusked Frog (v)	×	He, R, Sp	AGRT	191
Myobatrachidae	*Crinia signifera*	Common Froglet (v)	×	He, Sp	GS	26
Myobatrachidae	*Lechriodus fletcheri*	Fletcher's Frog (v)	×	He, Sp	RST	8
Myobatrachidae	*Limnodynastes ornatus*	Ornate Burrowing Frog		Sp	G	1
Myobatrachidae	*Limnodynastes peronii*	Brown-striped Frog	×	He, R, Sp	GRS	20
Myobatrachidae	*Mixophyes fasciolatus*	Great Barred Frog (v)	×	He, R, Sp	GRST	25
Myobatrachidae	*Mixophyes iteratus*	Giant Barred Frog (TS) (v)	×	He, R, Sp, Ta	ART	132
Myobatrachidae	*Pseudophryne coriacea*	Red-backed Toadlet (v)	×	A, He, PF	RST	192
Myobatrachidae	*Uperoleia fusca*	Dusky Toadlet (v)	×	A, He, PF	GS	9
Reptiles						
Gekkonidae	*Saltuarius swaini*	Southern Leaf-tailed Gecko (v)	×	PF, R, Sp	GRS	17
Pygopidae	*Lialis burtonis*	Burton's Snake-lizard		D, Sp	GS	3

Family	Species	Common name	S	M	H	R
Pygopidae	*Pygopus lepidopodus*	Common Scaly-foot	×	D	S	1
Varanidae	*Varanus varius*	Lace Monitor	×	C, D, R	GRST	67
Agamidae	*Hypsilurus spinipes*	Southern Angle-headed Dragon		D	R	B
Agamidae	*Physignathus lesueurii*	Eastern Water-Dragon	×	D, Sp, R	ART	32
Agamidae	*Pogona barbata*	Eastern Bearded Dragon		D	S	1
Scincidae	*Calyptotis ruficauda*	Southern Calyptotis (v)	×	A, B, PF	GS	29
Scincidae	*Ctenotus robustus*	Striped Skink	×	A, D	G	9
Scincidae	*Cyclodomorphus gerrardii*	Pink-tongued Skink (v)		R, Sp	ST	8
Scincidae	*Egernia frerei*	Major Skink	×	A, D	GS	10
Scincidae	*Egernia major*	Land Mullet	×	C, D, R	RST	31
Scincidae	*Egernia mcpheei*	McPhee's Skink		D	S	1
Scincidae	*Eulamprus martini*	Martin's Bar-sided Skink (v)	×	A, D	GS	17
Scincidae	*Eulamprus murrayi*	Murray's Skink (v)	×	A, B, D, PF, R	RST	28
Scincidae	*Eulamprus tenuis*	Bar-sided Skink (v)		D	R	1
Scincidae	*Lampropholis delicata*	Grass Skink (v)	×	A, B, D, PF	GRST	618
Scincidae	*Ophioscincus truncatus*	Short-limbed Snake-skink (v)	×	A, PF	RS	4
Scincidae	*Saiphos equalis*	Three-toed Skink (v)	×	A, PF	S	3
Scincidae	*Saproscincus rosei*	Rose's Skink (v)	×	D, PF	GRST	33
Scincidae	*Saproscincus spectabilis*	Gully Skink (v)	×	D, PF	RS	2
Scincidae	*Tiliqua scincoides*	Common Blue-tongue		D, R, Sp	GS	3
Typhlopidae	*Rhamphotyphlops nigrescens*	Blackish Blind Snake (v)		A, Sp	RST	12
Boidae	*Morelia spilota*	Coastal Carpet Python	×	D, R, Sp	GRST	31
Colubridae	*Boiga irregularis*	Brown Tree-Snake (v)		D, R, Sp	GRST	16
Colubridae	*Dendrelaphis punctulata*	Green Tree-Snake (v)	×	D, R	RST	17
Elapidae	*Cacophis krefftii*	Krefft's Dwarf Snake (v)	×	A, PF, R, Sp	RST	13
Elapidae	*Cacophis squamulosus*	Golden-crowned Snake (v)		A, R, Sp	GRST	16
Elapidae	*Demansia psammophis*	Yellow-faced Whipsnake (v)	×	A, B, D, I, R	GRST	22
Elapidae	*Hemiaspis signata*	Marsh Snake	×	D, R	RST	4
Elapidae	*Hoplocephalus stephensii*	Stephens' Banded Snake (TS) (v)		A, D, R, Sp	RST	10
Elapidae	*Pseudechis porphyriacus*	Red-bellied Black Snake		D	ARS	5
Elapidae	*Rhinoplocephalus nigrescens*	Eastern Small-eyed Snake	×	B, R, Sp	GRST	24
Elapidae	*Tropidechis carinatus*	Rough-scaled Snake (v)		R, Sp	RST	9
Elapidae	*Vermicella annulata*	Bandy-Bandy (v)		R, Sp	GS	2
Cheluidae	*Emydura macquarii*	Macquarie Turtle (v)	×	D,Tu	A	54
Birds						
Megapodiidae	*Alectura lathami*	Australian Brush-turkey	×	D, I, R, Sn	RST	27
Anhingidae	*Anhinga melanogaster*	Darter		D	H	1
Phalacrocoracidae	*Phalacrocorax melanoleucos*	Little Pied Cormorant	×	D	A	2
Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant		D, Sp	AH	2
Pelecanidae	*Pelecanus conspicillatus*	Australian Pelican	×	D	H	2
Ardeidae	*Ardea pacifica*	White-necked Heron		D	AT	2
Ardeidae	*Aredea ibis*	Cattle Egret		D, Sp	AR	1
Ardeidae	*Nycticorax caledonicus*	Nankeen Night Heron		D	ART	4
Ardeidae	*Ixobrychus flavicollis*	Black Bittern (TS)		D	AR	1
Accipitridae	*Pandion haliaetus*	Osprey (TS)	×	D	H	1
Accipitridae	*Aviceda subcristata*	Pacific Baza	×	D, He	GRS	8
Accipitridae	*Elanus axillaris*	Black-shouldered Kite		D	G	3

APPENDIX I

Family	Species	Common name	S	M	H	R
Accipitridae	*Haliastur indus*	Brahminy Kite	×	D	H	1
Accipitridae	*Haliaeetus leucogaster*	White-bellied Sea-Eagle	×	D	HS	8
Accipitridae	*Accipiter novaehollandiae*	Grey Goshawk	×	D	S	7
Accipitridae	*Accipiter cirrhocephalus*	Collared Sparrowhawk	×	D	GS	3
Accipitridae	*Aquila audax*	Wedge-tailed Eagle	×	D	HS	4
Accipitridae	*Hieraaetus morphnoides*	Little Eagle	×	D, He	GHS	7
Falconidae	*Falco longipennis*	Little Falcon		D	GS	2
Turnicidae	*Turnix phyrrothorax*	Red-chested Button-quail		R	T	1
Charadriidae	*Vanellus miles*	Masked Lapwing	×	He	H	2
Columbidae	*Columba leucomela*	White-headed Pigeon	×	D, He	RST	44
Columbidae	*Streptopelia chinensis*	Spotted Turtledove *		D, He	S	2
Columbidae	*Macropygia amboinensis*	Brown Cuckoo-dove	×	D, He	GRST	99
Columbidae	*Chalcophaps indica*	Emerald Dove		D	R	1
Columbidae	*Geopelia humeralis*	Bar-shouldered Dove	×	He	S	2
Columbidae	*Leucosarcia melanoleuca*	Wonga Pigeon	×	D, He	GRST	65
Columbidae	*Ptilinopus magnificus*	Wompoo Fruit-Dove (TS)	×	D, He	GRST	77
Columbidae	*Ptilinopus regina*	Rose-crowned Fruit-Dove (TS)	×	D, He	RST	30
Columbidae	*Lopholaimus antarcticus*	Topknot Pigeon	×	D, He, I	RST	41
Cacatuidae	*Calyptorhynchus lathami*	Glossy Black Cockatoo (TS)		D, I	GS	6
Cacatuidae	*Calyptorhynchus funereus*	Yellow-tailed Black-Cockatoo	×	D, He	GRST	50
Cacatuidae	*Cacatua roseicapilla*	Galah	×	D	GS	7
Psittacidae	*Trichoglossus haematodus*	Rainbow Lorikeet	×	D, He	GRST	135
Psittacidae	*Trichoglossus chlorolepidotus*	Scaly-breasted Lorikeet	×	D, He	GRST	56
Psittacidae	*Glossopsitta pusilla*	Little Lorikeet	×	D, He	ST	3
Psittacidae	*Alisterus scapularis*	King Parrot	×	D, He	GRST	113
Psittacidae	*Platycercus elegans*	Crimson Rosella	×	D, He, I	GST	35
Psittacidae	*Platycercus eximius*	Eastern Rosella	×	D, He	GST	13
Cuculidae	*Cacomantis flabelliformis*	Fan-tailed Cuckoo	×	D, He	GRST	60
Cuculidae	*Chrysococcyx lucidus*	Shining Bronze-Cuckoo		D	T	1
Cuculidae	*Eudynamys scolopacea*	Common Koel	×	D, He	GST	11
Cuculidae	*Scythrops novaehollandiae*	Channel-billed Cuckoo	×	D, He	GRS	7
Centropodidae	*Centropus phasianinus*	Pheasant Coucal	×	D, He	GST	17
Strigidae	*Ninox connivens*	Barking Owl (TS)		He	T	T
Strigidae	*Ninox strenua*	Powerful Owl (TS)	×	CP, He, Sp	RST	12
Strigidae	*Ninox novaeseelandiae*	Southern Boobook	×	D, He, Sp	GRST	111
Tytonidae	*Tyto alba*	Barn Owl		Sp	G	1
Tytonidae	*Tyto tenebricosa*	Sooty Owl (TS)	×	CP, He, Sp	RS	6
Podargidae	*Podargus strigoides*	Tawny Frogmouth	×	He, Sp	GST	17
Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar	×	He	RT	28
Apodidae	*Hirundapus caudacutus*	White-throated Needletail	×	D	H	105
Alcedinidae	*Alcedo azurea*	Azure Kingfisher	×	D	ART	20
Halcyonidae	*Dacelo novaeguineae*	Laughing Kookaburra	×	D, He	GRST	168
Halcyonidae	*Todiramphus sanctus*	Sacred Kingfisher	×	D, He	GRST	71
Coraciidae	*Eurystomus orientalis*	Dollarbird	×	D, He	GRST	42
Pittidae	*Pitta versicolor*	Noisy Pitta	×	C, D, He, I	RST	35
Menuridae	*Menura novaehollandiae*	Superb Lyrebird	×	D, He, I	GRST	135
Climacteridae	*Cormobates leucophaeus*	White-throated Treecreeper	×	D, He	GRST	194
Climacteridae	*Climacteris erythrops*	Red-browed Treecreeper	×	D	S	1

Family	Species	Common name	S	M	H	R
Maluridae	*Malurus cyaneus*	Superb Fairy-wren		D	S	1
Maluridae	*Malurus lamberti*	Variegated Fairy-wren	×	D, He	GRST	94
Maluridae	*Malurus melanocephalus*	Red-backed Fairy-wren	×	D, He	GS	2
Pardalotidae	*Pardalotus punctatus*	Spotted Pardalote	×	D, He	GRST	232
Pardalotidae	*Pardalotus striatus*	Striated Pardalote	×	D, He	GS	34
Pardalotidae	*Sericornis citreogularis*	Yellow-throated Scrubwren	×	D, E, He, I	RST	94
Pardalotidae	*Sericornis frontalis*	White-browed Scrubwren	×	D, He, R	RST	80
Pardalotidae	*Sericornis magnirostris*	Large-billed Scrubwren	×	D, He	RST	103
Pardalotidae	*Gerygone mouki*	Brown Gerygone	×	D, He	GRST	290
Pardalotidae	*Gerygone olivacea*	White-throated Gerygone		D	GST	4
Pardalotidae	*Acanthiza pusilla*	Brown Thornbill	×	D, He	GRST	114
Pardalotidae	*Acanthiza nana*	Yellow Thornbill		D	RST	3
Pardalotidae	*Acanthiza lineate*	Striated Thornbill	×	D	GST	52
Meliphagidae	*Anthochaera carunculata*	Red Wattlebird	×	D	G	1
Meliphagidae	*Anthochaera chrysoptera*	Little Wattlebird		D	G	1
Meliphagidae	*Philemon corniculatus*	Noisy Friarbird	×	D, He	GRST	10
Meliphagidae	*Entomyzon cyanotis*	Blue-faced Honeyeater	×	D	S	1
Meliphagidae	*Manorina melanocephala*	Noisy Miner		D, He	G	1
Meliphagidae	*Meliphaga lewinii*	Lewin's Honeyeater	×	D, He	GRST	505
Meliphagidae	*Lichenostomus chrysops*	Yellow-faced Honeyeater	×	D, He	GST	35
Meliphagidae	*Melithreptus lunatus*	White-naped Honeyeater		D	S	2
Meliphagidae	*Philidonyris nigra*	White-cheeked Honeyeater	×	D	S	1
Meliphagidae	*Acanthorhynchus tenuirostris*	Eastern Spinebill	×	D, He	GRST	52
Meliphagidae	*Myzomela sanguinolenta*	Scarlet Honeyeater	×	D, He	GRST	28
Petroicidae	*Petroica rosea*	Rose Robin	×	D	T	1
Petroicidae	*Tregallasia capito*	Pale-yellow Robin	×	D, He	RST	69
Petroicidae	*Eopsaltria australis*	Eastern Yellow Robin	×	D, He	GRST	149
Orthonychidae	*Orthonyx temminckii*	Logrunner	×	D, He	RST	63
Cinclosomatidae	*Psophodes olivaceus*	Eastern Whipbird	×	D, He	RST	236
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella	×	D	GS	3
Pachycephalidae	*Falcunculus frontatus*	Crested Shrike-tit	×	D, He	ST	19
Pachycephalidae	*Pachycephala pectoralis*	Golden Whistler	×	D, He	GRST	206
Pachycephalidae	*Pachycephala rufiventris*	Rufous Whistler	×	D, He	ST	5
Pachycephalidae	*Colluricincla megarhyncha*	Little Shrike-thrush	×	D	R	4
Pachycephalidae	*Colluricincla harmonica*	Grey Shrike-thrush	×	C, D, He	GRST	253
Dicruridae	*Monarcha melanopsis*	Black-faced Monarch	×	D, He	GRST	83
Dicruridae	*Monarcha trivirgatus*	Spectacled Monarch	×	D, He	RST	47
Dicruridae	*Myiagra rubecula*	Leaden Flycatcher	×	D, He	GT	10
Dicruridae	*Grallina cyanoleuca*	Magpie-lark		-	-	R
Dicruridae	*Rhipidura rufifrons*	Rufous Fantail	×	D, He	GRST	47
Dicruridae	*Rhipidura fuliginosa*	Grey Fantail	×	D, He	GRST	283
Dicruridae	*Rhipidura leucophrys*	Willie Wagtail	×	D, He	G	2
Dicruridae	*Dicrurus bracteatus*	Spangled Drongo	×	D, He	GRST	64
Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike	×	D, He	GRST	86
Campephagidae	*Coracina lineata*	Barred Cuckoo-shrike (TS)	×	D	G	1
Campephagidae	*Coracina papuensis*	White-bellied Cuckoo-shrike		D	GS	2
Campephagidae	*Coracina tenuirostris*	Cicadabird	×	D, He	GRST	58
Oriolidae	*Oriolus sagittatus*	Olive-backed Oriole	×	D, He	ST	22

Family	Species	Common name	S	M	H	R
Oriolidae	*Sphecotheres viridis*	Figbird	×	D, He	GRT	18
Artamidae	*Artamus leucorhynchus*	White-breasted Woodswallow		D, He	H	3
Artamidae	*Cracticus torquatus*	Grey Butcherbird	×	He	RST	23
Artamidae	*Cracticus nigrogularis*	Pied Butcherbird	×	D, He	GS	23
Artamidae	*Gymnorhina tibicen*	Australian Magpie	×	D, He	GST	59
Artamidae	*Strepera graculina*	Pied Currawong	×	D, He	GRST	224
Paradisaeidae	*Ptiloris paradiseus*	Paradise Riflebird		-	-	R
Corvidae	*Corvus orru*	Torresian Crow	×	D, He	GRST	150
Ptilonorhynchidae	*Ailuroedus crassirostris*	Green Catbird	×	D, He	RST	175
Ptilonorhynchidae	*Sericulus chrysocephalus*	Regent Bowerbird	×	D	RST	23
Ptilonorhynchidae	*Ptilonorhynchus violaceus*	Satin Bowerbird	×	D, He, I	GRST	110
Passeridae	*Neochmia temporalis*	Red-browed Finch	×	D, He, R	RST	85
Dicaeidae	*Dicaeum hirundinaceum*	Mistletoebird	×	D, He	GS	14
Hirundinidae	*Hirundo neoxena*	Welcome Swallow	×	D, I	GST	15
Hirundinidae	*Hirundo nigricans*	Tree Martin	×	D	G	1
Zosteropidae	*Zosterops lateralis*	Silvereye	×	D, He	GRST	90
Muscicapidae	*Zoothera heinei*	Russet-tailed Thrush (v)	×	D, R	RT	8
Sturnidae	*Sturnus vulgaris*	Common Starling *		-	-	R
Mammals						
Ornithorhynchidae	*Ornithorhynchus anatinus*	Platypus	×	D, Sp	A	10
Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna	×	D, R, Sp	GRST	14
Dasyuridae	*Antechinus stuartii*	Brown Antechinus (v)	×	B, E, Pr, Sp	GRST	106
Dasyuridae	*Sminthopsis murina*	Common Dunnart	×	Pr	-	1
Peramelidae	*Isoodon macrourus*	Northern Brown Bandicoot	×	Pr, R, Sp	GST	18
Peramelidae	*Perameles nasuta*	Long-nosed Bandicoot	×	He, Pr, Sp	RST	36
Phascolarctidae	*Phascolarctos cinereus*	Koala (TS)	×	D, He, I, Sp	GS	25
Burramyidae	*Cercartetus nanus*	Eastern Pygmy Possum (TS)		Sn	-	1
Petauridae	*Petaurus australis*	Yellow-bellied Glider (TS)	×	Sp, He	RST	39
Petauridae	*Petaurus breviceps*	Sugar Glider	×	He, Pr, Sp	GRST	16
Pseudocheiridae	*Petauroides volans*	Greater Glider	×	Sp	ST	11
Pseudocheiridae	*Pseudocheirus peregrinus*	Common Ringtail Possum	×	Pr, Sp	RT	7
Phalangeridae	*Trichosurus caninus*	Mountain Brushtail Possum	×	C, Pr, Sp, R	GRT	22
Phalangeridae	*Trichosurus vulpecula*	Common Brushtail Possum	×	C, I, Pr, Sp	GRS	100
Macropodidae	*Thylogale thetis*	Red-necked Pademelon	×	I, Pr, Sp	RST	11
Macropodidae	*Wallabia bicolor*	Swamp Wallaby	×	D, I, Pr, R, Sp	GRST	92
Pteropidae	*Pteropus poliocephalus*	Grey-headed Flying Fox (TS)	×	He, Sp	GHRST	284
Pteropidae	*Pteropus scapulatus*	Little Red Flying Fox		He, Sp	GS	2
Rhinolophidae	*Rhinolophus megaphyllus*	Eastern Horseshoe Bat	×	Ha	RT	2
Vespertilionidae	*Chalinolobus morio*	Chocolate Wattled Bat (v)	×	Ha	S	2
Vespertilionidae	*Chalinolobus gouldi*	Gould's Wattled Bat	×	U	GS	11
Vespertilionidae	*Kerivoula papuensis*	Golden-tipped Bat (TS)	×	Ha	R	1
Vespertilionidae	*Miniopterus australis*	Little Bentwing Bat (TS)	×	Ha	RST	10
Vespertilionidae	*Miniopterus schreibersii*	Large Bentwing Bat (TS)	×	U	GS	3
Vespertilionidae	*Myotis macropus*	Large-footed Myotis (TS)		U	R	L
Vespertilionidae	*Nyctophilus gouldi*	Gould's Long-eared Bat (v)	×	A, Ha, U	RST	25
Vespertilionidae	*Scoteanax rueppellii*	Greater Broad-nosed Bat (TS)	×	Ha, U	GRS	7
Vespertilionidae	*Scotorepens orion*	Eastern Broad-nosed Bat	×	U	GS	4
Vespertilionidae	*Scotorepens* sp.	Undescribed Broad-nosed Bat	×	U	RS	3

APPENDIX I

Family	Species	Common name	S	M	H	R
Vespertilionidae	*Vespadelus darlingtoni*	Large Forest Bat		U	R	L
Vespertilionidae	*Vespadelus pumilus*	Eastern Forest Bat (v)	×	Ha, U	GRS	28
Vespertilionidae	*Vespadelus vulturnus*	Little Forest Bat	×	U	GRS	4
Molossidae	*Mormopterus* sp. 1	Eastern Freetail Bat	×	U	GS	7
Molossidae	*Nyctinomus australis*	White-striped Mastiff Bat	×	U	G	1
Muridae	*Hydromys chrysogaster*	Water Rat	×	Pr, R, Sp	ART	8
Muridae	*Melomys cervinipes*	Fawn-footed Melomys (v)	×	E, Pr, R, Sn, Sp	RST	53
Muridae	*Rattus fuscipes*	Bush Rat	×	C, E, PF, Pr	GRST	74
Muridae	*Rattus lutreolus*	Swamp Rat	×	E	T	2
Muridae	*Rattus rattus*	Black Rat *	×	Pr	-	4
Muridae	*Mus musculus*	House Mouse *	×	Pr	-	2
Canidae	*Canis lupus*	Dingo		D	RS	2
Canidae	*Canis familiaris/* *Canis lupus*	Feral Dog */Dingo	×	I, Pr	GRST	60
Canidae	*Vulpes vulpes*	Red Fox *	×	D, Pr, Sp	GRST	46
Felidae	*Catus felis*	Feral Cat *	×	Pr, R, Sp	S	7
Leporidae	*Oryctolagus cuniculus*	European Rabbit *	×	I, Pr	S	3
Leporidae	*Lepus capensis*	Brown Hare *		Sp	R	2
Bovidae	*Bos taurus*	Domestic Cow *	×	I, Pr, Sp	S	4

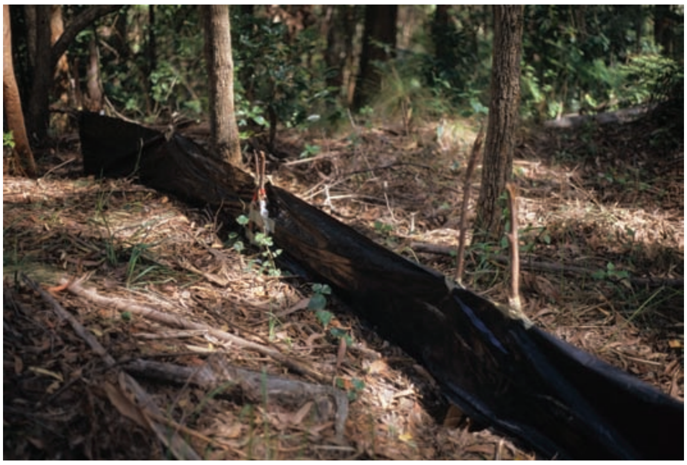
APPENDIX 2

Appendix 2. Summary of threatened species records noted in Bruxner-Ulidarra study.

Species	Summary of observations
Giant Barred Frog *Mixophyes iteratus*	Recorded Sept-May near streams in rainforest and tall open forest. Typically recorded sitting quietly on the forest floor or calling from concealed locations on stream edges.
Stephens' Banded Snake *Hoplocephalus stephensii*	Majority of live sightings were of animals active on the ground at night (5 animals) but also included 1 active on the ground by day and 1 found in a diurnal shelter site (under fallen timber at the base of a tree). Three animals were collected dead-on-road over a 2 year period. Active Nov-Feb.
Black Bittern *Ixobrychus flavicollis*	Single bird seen by day in typical cryptic bittern pose on edge of remnant pool in a dry 3rd order stream bed in rainforest, during drought in Jan 2002.
Osprey *Pandion haliaetus*	Scarce visitor from the adjacent coastal zone. Pair of birds observed flying high over eastern part of study area in Feb 2002.
Wompoo Fruit-dove *Ptilinopus magnificus*	Commonly recorded; present throughout the year. Most records were of birds calling from canopy in rainforest. Also recorded visiting an isolated fig tree in grassy open forest. Nesting recorded Dec 1999: simple stick nest 15m above ground in outer branch of tree in rainforest.
Superb Fruit-dove *Ptilinopus superbus*	**No records from the study area.** A bird found dead after collision with a window on the coastal plain 1 km east of Bruxner Park in Oct 2001 was identified by the senior author. Likely to be a sparse seasonal visitor to rainforest in the study area.
Rose-crowned Fruit-Dove *Ptilinopus regina*	Seasonal visitor Nov-March. Most records were of birds calling from canopy in rainforest.
Glossy Black-cockatoo *Calyptorhynchus lathami*	Uncommon in shrubby open forest and grassy open forest. Pair of birds seen feeding in *Allocasuarina littoralis* trees on 3 dates Jan-Feb 2003, with other records based on feeding litter (chewed cones).
Barking Owl *Ninox connivens*	One report from study area. Heard calling in tall open forest in northern part of Bruxner Park in Sept 1991 by T. Tweedie (R. Kavanagh Department of Primary Industries pers. comm.). Atypical habitat and possibly a transient bird moving through the area.
Powerful Owl *Ninox strenua*	Sparse resident: recorded all seasons. Most records were of birds calling at night from canopy and emergents in tall open forest and the edges of rainforest.

Species	Summary of observations
Masked Owl *Tyto novaehollandiae*	**No records from the study area.** A bird was observed following call playback in Orara East State Forest 1 km west of Ulidarra National Park in June 2000 (Forests NSW unpublished data). Potentially a sparse resident of shrubby open forest in the study area.
Sooty Owl *Tyto tenebricosa*	Sparse resident of rainforest and shrubby open forest: recorded in all seasons. Most records were of calling birds.
Barred Cuckoo-shrike *Coracina lineata*	Flock of 8 birds moving north through grassy open forest in March 2000.
Spotted-tailed Quoll *Dasyurus maculatus*	**No records from the study area.** Single adult caught by the senior author in the Coffs Harbour urban area 2km south of study area in July 1998, close to a vegetated drainage line originating in Bruxner Park. Likely to be a sparse resident of Bruxner-Ulidarra.
Koala *Phascolarctos cinereus*	Widespread but uncommon in shrubby open forest and grassy open forest, with most records from the eastern and southern sections. Favoured food trees were Tallowwood *E. microcorys* and Small-fruited Grey Gum *E. propinqua*.
Eastern Pygmy Possum *Cercatetus nanus*	Single record; as prey of a Stephens' Banded Snake in April 1997. Also recorded 0.5 km west of Ulidarra National Park in June 2000 (Forests NSW unpublished data).
Yellow-bellied Glider *Petaurus australis*	Widespread resident with an estimated five group territories identified. Recorded all months. Most records were from tall open forest and shrubby open forest occurring at the heads or sides of rainforest gullies.
Grey-headed Flying-fox *Pteropus poliocephalus*	Common nocturnal visitor to all parts of the study area throughout the year, commuting nightly from a camp on Coffs Creek on the coastal plain (3 km south). Recorded feeding in rainforest canopy and on Blackbutt and Tallowwood blossoms in eucalypt forest.
Golden-tipped Bat *Kerivoula papuensis*	Rarely recorded: two animals trapped together along a rainforest stream in Dec 2001.
Little Bentwing-bat *Miniopterus australis*	Widely recorded March-Nov 2001 in rainforest, tall open forest and shrubby open forest. Maximum of 5 animals trapped together.
Large Bentwing-bat *Miniopterus schreibersii*	Uncommon in grassy open forest and shrubby open forest. Recorded Nov 2001-Jan 2002.
Large-footed Myotis *Myotis macropus*	Recorded along rainforest streams in Feb 2003 (Lloyd 2004).
Greater Broad-nosed Bat *Scoteanax rueppellii*	Uncommon but widespread Oct 2001-Jan 2002. Recorded along a rainforest stream and in shrubby open forest and grassy open forest.

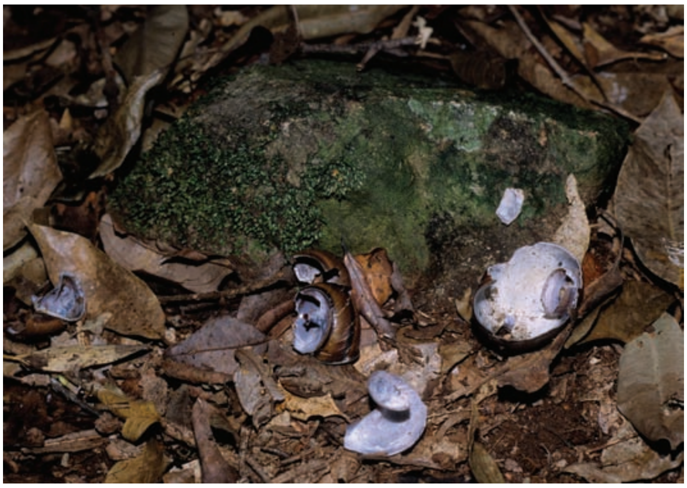
Appendix 3



Pitfall-trapping provided records of small ground-active and fossorial frogs and reptiles including *Uperoleia fusca*, *Ophioscincus truncatus*, *Saiphos equalis* and *Saproscincus spectabilis*, as well as the occasional juvenile *Rattus fuscipes*.

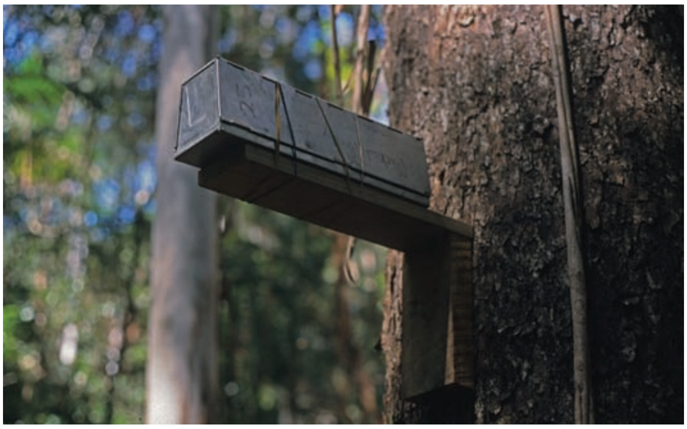
Photo, M.J. Murphy

APPENDIX 3



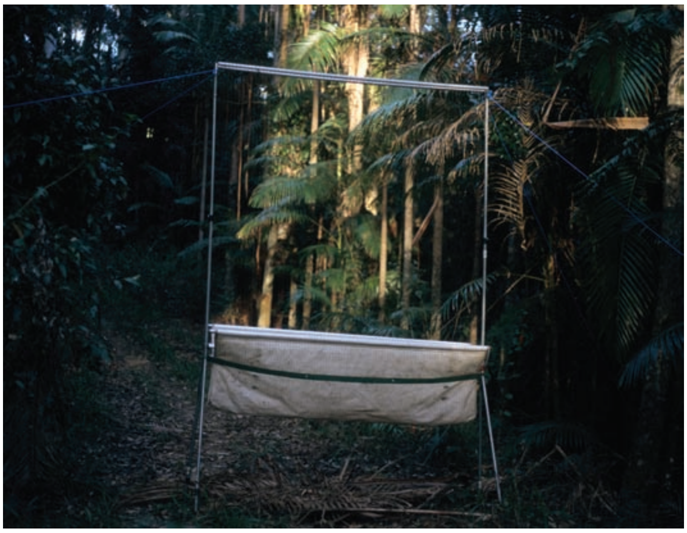
This rock surrounded by broken shells of the land snails *Hedleyella falconeri* (Caryodidae) and *Thersites novaehollandiae* (Camaenidae) provided indirect evidence of the Noisy Pitta *Pitta versicolor*.

Photo, M.J. Murphy



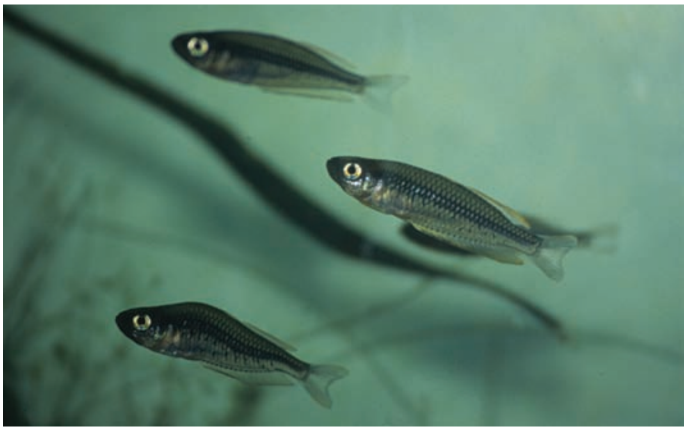
Elliott traps attached to tree trunks 2m above the ground captured *Antechinus stuartii* and *Melomys cervinipes*.

Photo, M.J. Murphy



This harp trap, set along a track in tall open forest likely to be used as a fly way by microchiropteran bats, captured *Nyctophilus gouldi* and *Rhinolophus megaphyllus*.

Photo, M.J. Murphy



Rhadinocentrus ornatus was the most commonly recorded fish and is close to its southern limit in the Bruxner-Ulidarra study area.

Photo, M.J. Murphy

APPENDIX 3

The endangered *Mixophyes iteratus* was found at night close to streams in rainforest and tall open forest.

Photo, M.J. Murphy

Litoria wilcoxii was a common species of streamside habitats. This frog, only recognised as a distinct species in 2004, demonstrates the value of supporting field surveys with voucher specimens.

Photo, M.J. Murphy

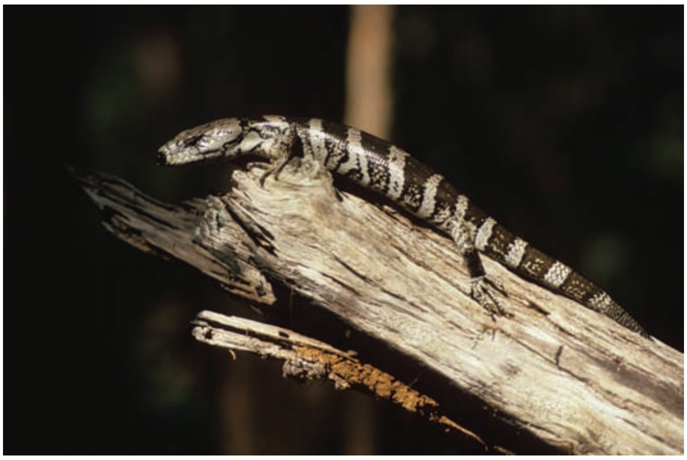
Litoria chloris is an arboreal frog which descended to the ground to breed communally in puddles after rain.

Photo, M.J. Murphy

Egernia frerei is a large, secretive lizard which reaches its southern limit at Coffs Harbour.

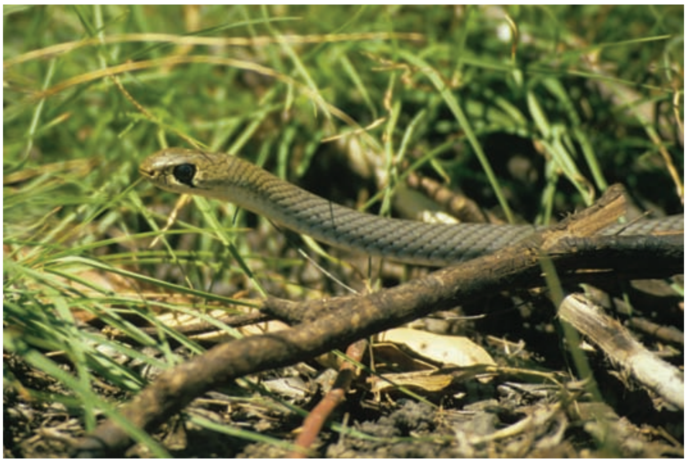
Photo, M.J. Murphy

APPENDIX 3



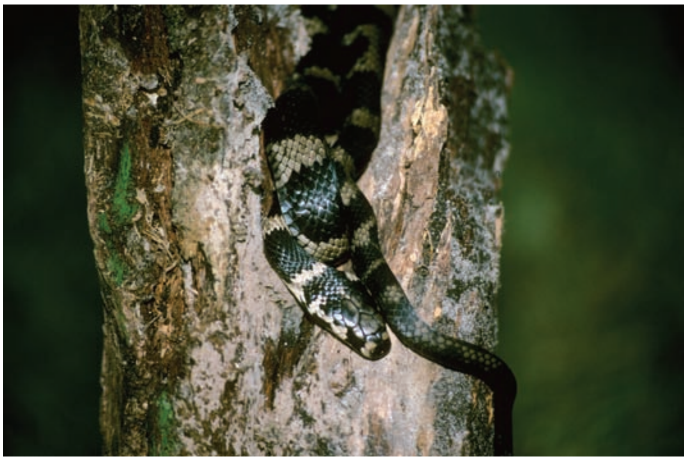
The striking *Cyclodomorphus gerrardii* was usually found at dusk in shrubby open forest and tall open forest.

Photo, M.J. Murphy



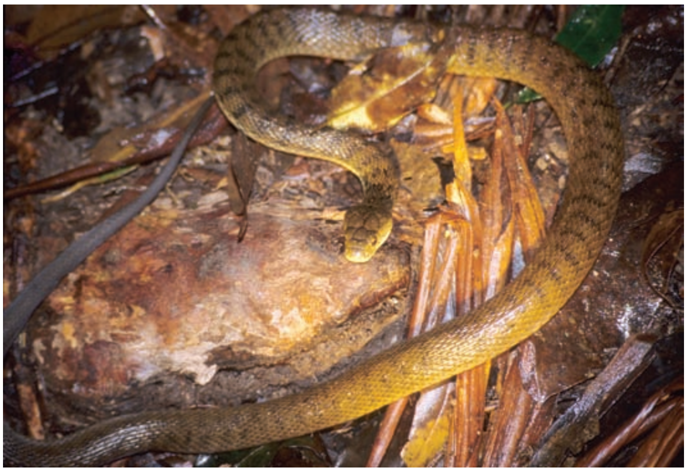
Opportunistic surveying over an extended period identified a diverse snake fauna. *Demansia psammophis*, a fast-moving diurnal hunter of lizards, was widespread in the study area but most commonly seen in grassy open forest.

Photo, M.J. Murphy



The threatened *Hoplocephalus stephensii* requires large areas of forest with abundant hollow-bearing trees and diverse vertebrate prey species.

Photo, M.J. Murphy



Tropidechis carinatus, a large nocturnal elapid, was found while spotlighting in rainforest and moist eucalypt forest.

Photo, M.J. Murphy

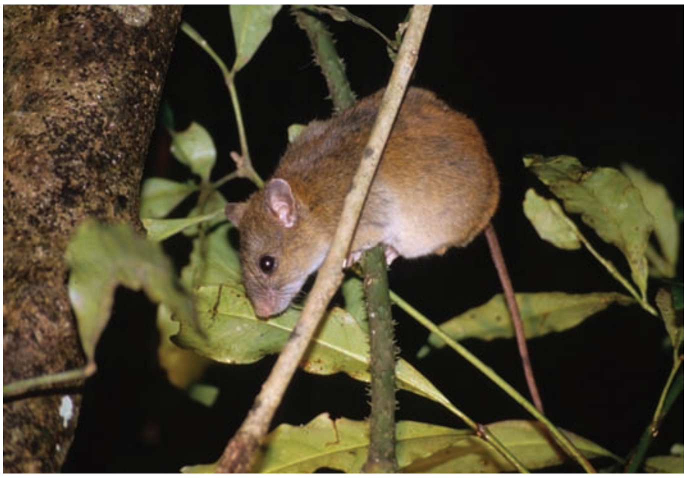
APPENDIX 3

The threatened Glossy Black-cockatoo *Calyptorhynchus lathami*, uncommon in the study area, requires large tree hollows for nesting.

Photo, M.J. Murphy

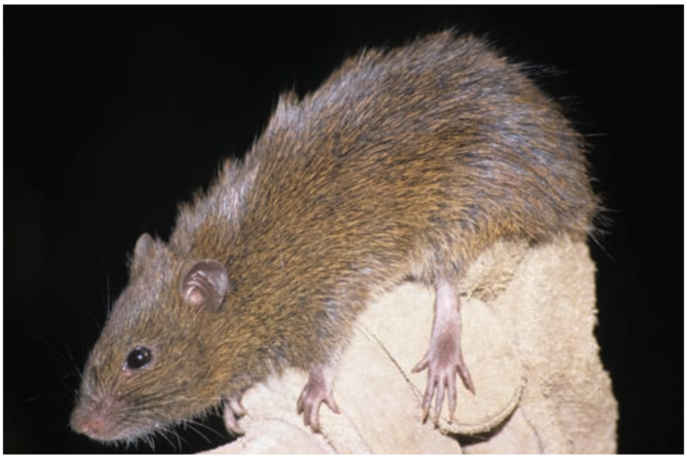
The threatened Koala *Phascolarctos cinereus* was detected by diurnal observation, by call recognition and spotlight at night and by identification of scats at the base of favoured food trees.

Photo, M.J. Murphy



The arboreal *Melomys cervinipes* was commonly recorded in rainforest and moist eucalypt forest by spotlighting, Elliott trapping and predator scat analysis.

Photo, M.J. Murphy



Elliott trapping provided the only records of *Rattus lutreolus* in the study area. This individual was trapped in tall open forest.

Photo, A. Gillespie and M.J. Murphy

APPENDIX 3

The threatened *Scoteanax rueppellii* is a hollow-roosting species which was recorded by both harp trapping and ultrasonic detection. This animal was trapped along a small stream in rainforest.

Photo, S.J. and M.J. Murphy

The threatened Wompoo Fruit-dove *Ptilinopus magnificus*, shown here perched high overhead in the rainforest canopy at Bruxner Park, was heard more often than seen. Conservation of both lowland and upland rainforest areas is critical to the survival of this mobile species.

Photo, M.J. Murphy

The shy and solitary Swamp Wallaby *Wallabia bicolor*, weighing up to 20 kg, was the largest native vertebrate recorded in the Bruxner-Ulidarra study area. This animal was observed by day in grassy open forest.

Photo, M.J Murphy

Addendum

Subsequent to the acceptance of this paper for publication in February 2009, three additional species recorded in this study have been listed as threatened (vulnerable) species under the NSW *Threatened Species Conservation Act* 1995: the Little Lorikeet (July 2009) and the Little Eagle and Varied Sittella (February 2010). This brings to 23 the number of threatened vertebrate species recorded or reported within the Bruxner-Ulidarra study area (current to November 2010). The following information is provided as an addendum to Appendix 2:

Species	Summary of observations
Little Eagle *Hieraaetus morphnoides*	Uncommon: recorded February-April 2000, May 2004 and October-November 2004. Most records were of single birds flying slowly over ridgetop grassy open forest and occasionally over shrubby open forest. A pair of birds was observed in an aerial display over ridgetop grassy open forest in October 2004.
Little Lorikeet *Glossopsitta pusilla*	Scarce in tall open forest and shrubby open forest. Small groups recorded feeding high in canopy of Flooded Gums in tall open forest in April and June 2000. Also recorded in canopy of shrubby open forest in June 2000.
Varied Sittella *Daphoenositta chrysoptera*	Scarce in shrubby open forest and grassy open forest. Small groups of about six birds recorded foraging on minor branches of eucalypt trees in shrubby open forest and grassy open forest in June and September 2000.

There have also been several relevant taxonomic changes, two of which are noted here. A reassessment of the Southern Leaf-tailed Gecko *Saltuarius swaini* by Couper *et al*. (2008) resulted in the recognition of two new species, with animals from the Bruxner-Ulidarra study area now identified as *Saltuarius moritzi*. The narrow-range camaenid land snail from grassy open forest in Bruxner Park FR was described as *Ponderconcha murphyi* by Clark (2009). Taxonomy is always a 'work in progress', and the lodging of voucher specimens in Museum collections is an important part of field surveys, allowing the results to remain current through the availability of reference material.

Lastly, the value of grassy open forest hill-tops in the study area as hill-topping sites by butterflies briefly noted in this paper has been documented in more detail by Murphy (in press).

Clark, S. 2009. A review of the land snail genus *Meridolum* (Gastropoda: Camaenidae) from central New South Wales, Australia. *Molluscan Research* **29(2):** 61-120.

Couper, P.J., Sadlier, R.A., Shea, G.M. and Worthington Wilmer, J. 2008. A reassessment of *Saltuarius swaini* (Lacertilia: Diplodactylidae) in southeastern Queensland and New South Wales; two new taxa, phylogeny, biogeography and conservation. *Records of the Australian Museum* **60:** 87-118.

Murphy, M.J. in press. Notes on the butterflies of Bruxner Park on the north coast of New South Wales, Australia. *The Victorian Naturalist*.